stance that the articles found in the graves in question evince no higher skill than that attained by the more advanced of the historically known tribes of North American Indians, there hardly remains any reasonable ground for not ascribing to such tribes the humble mortuary receptacles treated in this hasty sketch.

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ORGANIC PHYSICS.

BY CHARLES MORRIS.

(Continued from page 563, Vol. XVI.)

2. The Organic Function of Oxygen.

The subject here proposed is one to which considerable attention has been paid by inductive science, with the result of conclusively demonstrating that organic activity is strictly dependent upon the presence of oxygen, and that every animal, and each organ of every animal, displays an activity in close accordance with its supply of oxygen. This is about all that has been deduced from the facts observed, but is certainly not all that they indicate. Much wider deductions may be made; some, perhaps, only conjectural, yet others apparently unavoidable, and by their aid a fuller conception of the motor power of the animal kingdom may be gained. Such deductions must also include the vegetable kingdom, since it is now known that plants breathe oxygen as persistently as animals, and that they continue active only during their period of active oxygenation.

But to persistent vital activity nutrition is as essential as oxygenation. The one is the key that winds up the clock of life; the other is the spring that sets its wheels in motion, and frees its restrained energies. Oxygen eats into and breaks down the complex molecules of protoplasm. Nutrition rebuilds these molecules. Thus life forever swings, between limits of chemical analysis and synthesis. In the downward swing it bursts into full activity, and beats against the barriers of the outer world. In the upward swing it relapses into inactivity, and all its energies are employed in the chemical labor of forming new molecules of protoplasm.

These processes can hardly be simultaneous. The reduction of protoplasm by oxidation, and its reproduction in the opposite process cannot take place at once in the same cell.

Probably in every limited portion of tissue oxidation and repro-

duction of protoplasm take place successively. They may occur simultaneously in different regions of the same body, yet there is reason to believe that now the one, now the other, is the ruling agency in the body, as a whole, each having its period of special activity.

This conception has been vaguely approached by some physiologists, but does not seem to have been definitely laid down as a fixed principle of organic action. It is very evident that during the waking or active period oxygen is far more vigorously at work than during the sleeping or passive period. It eats its way into the tissues; it chemically reduces the complex molecules of their cells; it sets at liberty their locked-up energies, and it leaves these energies to be employed in the various modes of organic motion. The mind, the nerves and the muscles are now particularly active. The involuntary functions are also specially active. The heart and the lungs act vigorously, sending the requisite oxygen to every cell in the organism. The preparation of nutriment is also energetic. Food is swallowed and digested. It is absorbed into the blood current, and there undergoes certain chemical modifications. It exudes from the vessels as a nutritive plasma, and is laid up for subsequent use in immediate contiguity to the cells of the tissues.

During this period it is highly improbable that there is any active nutrition. Nutrition needs free energy, and locks up this energy in the molecules produced. But the free energy of the body is now otherwise engaged, and there can be little or none left for the needs of organic synthesis. Moreover, much of the free energy is used up in the selection and preparation of nutrient molecules, and their conveyance to the localities where they are likely to be needed. Thus one phase of the nutrient process is active, but not the final one. There is little or no assimilation of nutriment. The waking period is, therefore the one in which oxidation is in excess; in which the stored-up energies of the body are being set free, and used as animal activity, and in which the body is, as it were, dropping down hill, falling back chemically towards the mineral world.

This phase of life-action limits itself. The affinity for oxygen is largely satisfied, and loses vigor. The cells exposed to oxidation have had many of their complex molecules reduced, and have grown less susceptible to this form of chemism. Their affinity

for nutriment has correspondingly increased, while new nutrient molecules have been stored up in their vicinity. The tide of life turns. From running down it begins to run up. The process of assimilation gains the supremacy, and oxidation of the tissues in great part ceases. During this period there is a marked change in the conditions of life. Assimilation consumes energy. The chemical synthesis cannot go on unless energy be supplied. That which was yielded during the period of oxidation no longer remains in the body. It has been used up in various methods. Temperature energy remains, but that must be kept up, and cannot be reduced in aid of other purposes. It is evident, then, that while assimilation is specially active animal activity must decline or cease. Not only is there no store of energy for mental and muscular action, but there is none for chemical action. Energy must be provided for this purpose, and much of the oxygen which now enters the body is necessarily engaged in this new duty. Oxidation continues, but it is oxidation of the hydrocarbons of the blood or of other low-atomed molecules, to supply the energy required for the rebuilding of the tissues. The sleeping succeeds the waking state, and animal is replaced by vegetable activity.

It will be perceived, by the terms of this hypothesis, that there is required no actual cessation of the two life-processes. Each, in fact, has two separate phases. During the waking period oxygen is busy in the tissues, while nutriment is being actively absorbed, prepared and stored up for future use. During the sleeping period nutrition is busy in the tissues, while oxygen is partly engaged in reducing the innutritious ingredients of the blood and the tissues, and yielding energy for temperature and assimilation, and is partly stored up for future use. Thus each process aids the other, and each succeeds the other in its work upon the tissues. Now oxygen gains the mastery, life thrills in every nerve and muscle, the chemical molecules drop to a lower level of intricacy and the body springs into its active, waking state. Now nutrient affinity gains the mastery, vital activity ceases, the body is being lifted up hill preparatory to another fall, and the passive, sleeping state supervenes.

In plant life there is only one process, instead of two, as in animals. Plants always sleep. Oxidation is active, but it is similar in character to the oxidation that takes place in animals

during sleep. It is oxidation of the combustible materials of the sap current, and yields energy to assist in chemical synthesis. Thus plants display only one of the life processes. Their whole life is passed in the sleeping, assimilative state. They fail to attain the waking, active state.

This distinction is, indeed, not an absolute one. To a limited extent oxidation of the protoplasmic tissues takes place in plants, and to that extent motive energy is possible. In those organs of plants which are specially rich in protoplasm, the leaves and flowers, motor activity is frequently displayed; and in the meat-eating plants, in which chemical synthesis is less exhaustive of energy, there occur at times rapid and well-defined motions, with marked indications of nervous and muscular functions. As a rule, however, it may be said that the sleeping state is normal to plants, both the sleeping and waking states to animals.

Very probably in some of the simpler animals these variations in function take place with much greater frequency than in higher animals. They are periodical, but the periods rapidly succeed each other, so that there is little or no visible indication of a period of inactivity. A like rapid variation also appears to take place in certain tissues of the higher animals, as in the heart. This will be further considered in a later portion of this article.

It appears, from the foregoing considerations, that if we trace the processes of life to their basic condition, we are brought to the chemical activities of protoplasm. Whatever else protoplasm may contain, it certainly contains highly complex, albuminoid molecules, which are its active principles. And the activity of these molecules appears to be strictly chemical in character, and to consist of the following double process. They have an affinity for oxygen. which removes some of their elements, reduces their complexity of composition, and yields free energy. In this reduced state their affinity for oxygen weakens; they acquire an affinity for nutrient molecules, combine with the latter, lock up energy in doing so, and regain their molecular complexity. And life consists in the periodical succession of these two processes.

In all the higher phases of life there are mechanical appliances for the utilization of the energy set free in the first of these processes; but the basis of all life, its fundamental condition, is this chemical activity of albuminoid molecules. To comprehend life, then, we must first comprehend protoplasm; and some fuller consideration of the characteristics above given is desirable.

The life processes are not due to the single fact that oxidation of protoplasm yields unemployed energy. There is needed the secondary fact that protoplasm is so constituted as to make special use of this energy, by converting it into mass motion. Did it take only the general form of heat vibration, none of the phenomena of life could arise. We may reasonably ask, then, how does this conversion of free energy into mass motion take place, and what are its special conditions?

Fortunately we are not confined to the organic world for instances of this conversion. Similar phenomena occur in the inorganic world, and possibly the principle of action is in both cases the same. Parellels may readily be drawn between inorganic and organic motor activities, and a consideration of certain results of inorganic chemism may throw light on the phenomena of protoplasmic action.

In considering the motor energies of protoplasm they appear partly indefinite and partly definite; the former consisting of such motions as the streaming of protoplasm in plant cells, and the vague changes of form in the Rhizopods; the latter of the higher animal "modes of motion." The former is continuous, indefinite, general and seemingly purposeless; the latter is temporary, definite, local and with an evident purpose. Yet a close consideration of organic motions shows a connected series of steps between the two phases indicated, and evidences of similarity in their instigating causes, which go to show that they are alike in origin and character.

What is the source of the energy displayed in these motions? There is only one physical source apparent; namely, chemical change. In many instances chemical change evidently attends the motions of protoplasm. This chemical change is an oxidation, and no such movement ever takes place unless oxygen be present. Hence there is warrant for the assertion that all motion in protoplasm results from the action of motive force set free by oxidation, and that for such motion to long continue there must be periods of rest from physical action, during which nutrient molecules can be assimilated, and a condition of ready susceptibility to oxidation reproduced.

But there is an influencing cause of these motions, of essential importance. This is the contact of external substance with the surface of the protoplasmic mass. In nearly every case of animal

motion contact (or its mental resultant) is evidently necessary. Solid substance, or vibratory energy, touches the surface of the cell, or the extremity of conducting lines leading to the protoplasmic cell. An immediate, definite motion occurs in response. We call this sensitiveness, but a mere word explains nothing. The contact of external matter does not provide the motor force displayed, but it in some way sets it free. The force is yielded by some change which takes place in the cell, but this change is instigated by some outward pressure or irritation. And the motion which results is related in position and direction to the source of irritation. If this affect the whole cell the motion will be general and indefinite. If it affect a limited region of the cell, the motion will be local and definite.

In ascribing organic motions to chemical change we are not giving unknown powers to chemism. Inorganic chemical science yields numerous illustrative instances. Mass motion is a common result of chemical action. When a substance changes its character by variation in its chemical condition, a rearrangement of its molecules frequently takes place, causing visible motions, and an eventual change of form in the mass. So the movements of cell protoplasm may arise from molecular rearrangement, caused by chemical change; and the so-called contraction of muscular fibers is really but a change of form possibly due to the same cause.

In like manner the influence of external irritation over organic motion is far from being peculiar. It has many parallels in the inorganic world, of which a few may be here mentioned. Inorganic substances which combine but slowly, or not at all, when mixed and undisturbed, often combine rapidly and even explosively when exposed to external irritation. The cause of this sudden manifestation of chemical affinity is probably a vibration, which flings the molecules together, and thus aids their affinities. In the case of gunpowder, vigorous heat vibration causes instant and explosive combination of molecules. In other mixtures the vibration produced by a blow yield a like result. In like manner a mixture of hydrogen and chlorine gases, which remain uncombined in the dark, combines explosively if exposed to the vibratory influence of sunlight. In all these cases mass motions result, which are definite in direction if the substances be properly confined. A yet more significant instance of sensitiveness to vibra-

tory influence is that of photographic compounds. These can be made so exquisitely sensitive that the faintest touch of the rays of light produces instantaneous chemical change. The responses of protoplasm to touch are even less delicate than those of some of these inorganic substances.

We have considerable warrant for ascribing protoplasmic action to a like result of contact influence. It never takes place except oxygen be present. Probably it is necessary that oxygen should permeate, or be stored up in the protoplasmic mass, the molecules of oxygen and protoplasm being intimately mixed, like those of hydrogen and chlorine in the mixture above referred to. And in both cases the commingled molecules seem to resist the energy of chemical affinity until a vibratory motion, originating without, is sent through the mass, and flings them into closer contiguity. The mixture of oxygen and protoplasm, however, appears much more sensitive than that of hydrogen and chlorine. In the latter case only the vigorous vibrations of sunlight seem sufficient to induce combination. In the former case every source of vibration yields this effect, as might be expected from the high instability of protoplasm molecules, and the strong affinity of some of their elements for oxygen.

Various sources of vibratory influence exist in nature. First are the radiant vibrations of sound, heat, light and electricity, to all of which protoplasm seems susceptible. Next come several forms of direct contact, as of gaseous, liquid and solid substance, each of which may produce a vibratory thrill. Then there are the vibrations of inflowing or outflowing temperature. Perhaps still other sources of vibration exist, and to all alike protoplasm seems susceptible. Every vibration, even the slightest, from whatever source, which enters into and acts upon protoplasm, apparently induces combination with oxygen (if this element be present), with a consequent freeing of motor energy, and production of some physical change.

Yet, as it would prove destructive to all high animal life should the protoplasm of the cells be exposed to every vibratory thrill of outer nature, and forced to respond thereto, the body generally is covered with a protective coating, through which only the more vigorous vibrations produced by contact pressure and heat energy can pass, and is provided with nerve terminations specially adapted to receive impressions of such character. There are only two

channels through which the more specialized radiant vibrations can reach naked protoplasm; that of the eyes, which suffer only radiations of very high pitch to enter; and that of the ears, which admit only low pitch vibrations. There are two other organs, the nose and the tongue, through whose agency the finer contacts of gaseous and liquid matter reach the naked cell protoplasm. Hence the bodies of the higher animals are susceptible to every mode of contact of external moving energy, but of each in a limited region. It is not that all protoplasm is not equally susceptible to contact of every kind, but that the body protoplasm is shielded at every point from more than a limited range of contacts.

Such is not the case with the protoplasm of the lowest animals. It is exposed to every form of contact, and moves in response thereto. There are no arrangements to limit special contacts to special regions of the mass. The streaming of protoplasm in the plant cells very probably results from the action of light within these cells. We know that it becomes more energetic as the light grows stronger, and there is no evidence that it exists except where transparent tissues are exposed to light vibration. The movements of the Rhizopods are probably due to the same cause. They are apparently without external causation, yet if we consider them closely certain significant indications emerge. These creatures are surrounded by water, and their less definite motions may result from contact pressure of slight water currents. Possibly also light and heat rays may have some influence. In the creeping of the Rhizopods a more definite motion appears. Yet here there is solid contact, and the chemical change induced by this may be the acting cause of the declared production of pseudopodia in that direction, and the creeping translation of the whole body in consequence. Finally comes the most localized of all rhizopodal touch, that of food particles upon the pseudopodia. Immediately a limited and localized motion, specially related to the touching particles, results, and the affected protoplasm closes around and engulfs the touching substance. In the Rhizopod, then, we seem to have a progression from the most vague and general to the most localized and special motions, as touch varies from a faint and general to a vigorous and local influence.

In the Ciliata motion grows much more definite and localized.

Sensitiveness seems confined to special protrusions of the protoplasmic mass, while the remaining surface has lost its irritability. Possibly it has become sheathed in insensitive substance. Cilia are perhaps composed of naked protoplasm, and adapted to perform at once nervous and muscular duties. They may represent in the Protozoa the separate nerves and muscles of the Metazoa; and may also represent, in ciliated epithelial cells, the individual life function of all cells. Everywhere that cells are exposed to external contact they display receptive adaptations; but fail to do so when shielded from contact. The cilia must constantly feel the fine currents which can scarcely ever be absent from liquids. Thrills of vibration may thence be sent down into the protoplasmic mass, and oxidation induced. The energy arising may be reflected back into the cilia, as the most motile portions of the mass. As for their specially directed motions it is quite possible that they may be specially related to the mass, and free to move only in certain directions.

If the motor and sensory functions of single-celled animals are thus confined to minute filaments, the similar functions in the many-celled animals are likewise confined to cellular filaments or fibers, arranged to conduct vibratory energy in certain directions, and to yield motion to certain limbs and organs. The bodies of the higher animals are permeated by lines of conductive material, insulated from the surrounding tissue, and with their surface extremities consisting of naked protoplasm. These conducting lines lead to peculiarly arranged masses of fibers, into which are discharged the vibratory influences which they carry inward. Motor changes take place in these muscular fibers in response, and these changes are always accompanied by oxidation. Quite possibly the motor impulse which the nerve has received from external contact or pressure, is carried inward and delivered to the muscle as a vibratory energy, which induces chemical combination between the commingled oxygen and protoplasm molecules.

All the motor functions of the highest animals are unquestionably results of the physical character of protoplasm, and of its special arrangements. The principles of motor activity which we find in the Rhizopod exist in the man, and no others. Protoplasm, wherever found, is subject to rapid oxidation when external motor influence sends a vibratory thrill through it. This

oxidation yields an energy which manifests itself as mass motion. In the Rhizopod the whole cell is at once nerve and muscle. In the Ciliata these functions are confined to a differentiated portion of the cell. In the Hydra cells appear with nervous functions exteriorly and muscular interiorly. In the higher animals these functions are distributed to separate cells. But there is no evidence that the mode of motion in protoplasm anywhere differs. In all cases alike external impact causes internal vibration, rapid oxidation and quick change of form. The results of these changes depend on special conditions, combinations and attachments of cell masses. There is perhaps nothing peculiar in the muscle cell except its elongated shape. Variation from this shape towards a spherical one must considerably reduce the length of the mass, and produce the effect known as muscular contraction.

The true inorganic parallel to nerve conduction may not be the telegraph wire, as ordinarily assumed. It may have a closer analogy to a train of gunpowder, arranged in successive small masses, and so disposed that the explosion of each shall set fire to the next in the line. If we imagine at the end of the train a larger mass of confined gunpowder, its explosion would symbolize the action of the muscle. Contact with the nerve extremity yields a vibratory impulse, which is confined to the narrow nerve channel, and so conducted inwards. In its course it acts on other minute masses of protoplasm, inducing oxidation and a yielding of fresh energy. Such would seem to be the case from the observed invigoration of the nerve current in its flow. When the vibratory energy is discharged into the muscle it causes oxidation in a considerable mass of protoplasm. And animal motion is produced by the change of shape of the muscle fibers, just as inorganic motion is produced by the change of shape in a released spiral spring.

We define the active organs of the body as nerves and muscles simply because their duties are different, not from any fundamental difference of character. The time may come when the muscles will be looked upon as merely a special aggregation of nerve endings. It was formerly believed that the nerves terminated exteriorly to the muscle fibers, and affected them by some process of induction. But this belief is now abandoned by most anatomists, and it is held that the nerves penetrate the sarcolemma of the muscle fibers, while the nerve sheath becomes con-

tinuous with the muscle sheath. Thus the naked axis cylinder of the nerve comes into direct contact with the muscle substance, and divides until every muscle fiber has its distinct nerve. The nerve extremities spread out on the surface of the fiber into a peculiar plate-like mass. But Professor Gerlach asserts that this is not the true extremity of the nerve, but that it sends minute fibrils onward, which penetrate the muscle fiber, so that there is a most intimate union of nerve and muscle. In the unstriped muscles the nerves form delicate plexuses, and subdivide until a highly delicate intra-muscular network is produced. Frankenhauser traced minute fibrils from this network into the substance of the fiber, ending, as he believed, in the nucleolus of the cell. But Arnold asserts that a filament is continued through the cell, and rejoins the network without. Thus the nuclear fibril seems to be the nodal point of a fine intra-muscular network of nerves.

What should we deduce from these facts? The sarcolemma of the muscle fibers—by whose aid their separate motions are combined and communicated to the limbs or otherwise distributed—is but a continuation of the elastic sheath of the nerves. The nerves divide into minute fibrils in the muscles, and each muscle fiber appears to be but a mass of contractile matter aggregated around a delicate nerve extremity. The richly protoplasmic nerve plate may be an arrangement for a final invigoration of the nerve current, before entering the fiber. It is not found on the slow-moving unstriped muscles, and its purpose may be to aid the vigor and rapidity of movement of the voluntary muscles. From this point of view a muscle is simply a special aggregation of nerve extremities, each of which is surrounded by matter susceptible of rapid oxidation, while their sheaths are so combined and arranged as to be capable of exerting a powerful strain on the limbs or other organs. We may with some reason conclude, therefore, that the method of action in all protoplasm is but one; while the results are as many as there are diverse arrangements of cells.

There is a third constituent of the sensory and motor organism which it is important to here consider—the nerve cell or mass of cells; the ganglion. Under the hypothesis here advanced it might, at first thought, be looked upon as an aid in the process of nerve conduction; as a mass of protoplasm intended

by its oxidation to invigorate the nerve currents. Yet in all probability its purpose is the exact opposite of this; it acts to resist instead of to invigorate the current. The physiology of the nerve system yields evidences of this. One function of the brain cells is, perhaps, to resist the currents over the nerves, and prevent all sensory currents from producing reflex motions. In another portion of the nervous system—the sympathetic—ganglia are interposed in great numbers. There is reason to believe that they act to hinder the outflow of nerve currents. A slight action upon a sympathetic nerve fiber causes motion only in adjacent muscles. A more powerful action causes a wider series of motions, it being perhaps more capable of overcoming the resistance of the ganglia. But only a very powerful impulse is capable of forcing its way through the whole chain of ganglia and reaching the brain. Thus the action of the sympathetic nerves is usually limited to the production of reflex motions, and only affects the brain when the impulse is so energetic as to indicate danger to the economy. When thus called upon the mind is able to directly respond, through the cerebro-spinal fibers, of probably motor function, which accompany the sympathetic.

The anatomy of the nerve cell yields confirmation of this idea. It presents, indeed, a singular analogy to the expedient adopted in telegraphy for the same purpose. It is a "resistance coil" interposed in the nerve circuit. For the recent delicate microscopic investigation of the nerve cell has demonstrated that it is really a congeries of excessively fine fibrils. These penetrate every portion of the cell and its nucleus, and are continued outward by delicate rootlets, or by fibers. The rootlets probably form a network termination to the sensory nerves, and the fibers are the origin of the motor nerves.

As the fine wires in the resistance coil of the electric current check the flow, and permit the operator to control the quantity of electricity passing, or to completely prevent its passage, so may the cell fibrils interposed in the line of the conducting nerve, perform a like duty. Possibly, to a certain extent, the result is the same. The checked current of energy becomes converted into heat. But in one of the ganglia, the brain, it becomes consciousness, or mental energy, a process with which we are not here concerned. In regard to the apparent difference of gangliar termination in sensory and motor nerves, the network of

the former may aid in checking the current, the direct fiber of the latter may assist its subsequent flow.

This hypothesis greatly simplifies the conditions of the motor organism of animals. It consists fundamentally of fibers which permeate the body, and convey motor energy from without inward. At their extremities, and at intervals on their course, these fibers are reduced to minute fibrils, which check the flow of the current, and cause its lateral distribution as heat or vibratory energy. Cellular masses of protoplasm surround these fibrils, constituting the nerve and the muscle cells. The checked energy outflows into this protoplasm, and instigates chemical change there. In one relation of these cells the energy set free by the chemical action is locked up in the mental organism,—how we know not. In another relation it yields muscular contraction, and animal motion. In still other relations it may yield other effects, as above indicated in the sympathetic ganglia. But the fundamental principle is the same throughout. The flow of force is checked, wholly or partly tapped off from the fiber, and employed to instigate chemical action, from which important effects arise. Similarly in an electric circuit fine wires interposed check the current, and part of it outflows as heat which may be used to produce various effects, as the fine wires are surrounded by material differently acted on by heat, and differently arranged. The analogy is a singularly exact one.

If, as is undeniable, all animal activity is a utilization of the normal motions and changes of form in cell protoplasm, and if all these motions arise from oxidation induced by superficial contact with foreign matter, then all active life must depend upon contact influence, and any animal so situated as to feel at no part of its surface any force of pressure from foreign matter could not display the attributes of life. All life is a response to the finger touches of the world without, which set free the dormant energies within, and call them into responsive action. This may seem only partially true, since in the higher animals the mind instigates the greater part of the voluntary motions. Yet the mind has been built up under influences received from without. Whatever its innate character, its energies are resultants of former physical contact. Thus all our motions arise as results of immediate or of former contacts with the sensory nerve extremities. And it is doubtful if even the mind would arouse of itself

from sleep, and if all wakening is not due to external influence acting on the body, and through it affecting the mind.

The most simplified mode of activity in the higher animals is that of the ciliated epithelial cells, which seem to respond to the touch of mucus or other liquid substance. Their utility in the animal economy is, except in a few instances, very evident. But the principal mode of animal activity is that due to excitation of nerve extremities, and the consequent effect upon the muscles. What is known as voluntary motion is obviously due to contact of foreign matter with the external surface, its effects being produced through the intermediate agency of the mind. It has not been fully perceived, however, that all involuntary motion is due to a like cause. This is, indeed, acknowledged to be the case in the operations of digestion. The contact of food with the surface of the digestive cavities is the influencing cause of all that takes place. There are two distinct results of this contact. One is the peristaltic motion of the œsophagus, stomach and intestines, by which the food is kept in motion, and is gradually passed downward. The other is the action on the glands that aid digestion. This is also largely muscular, being principally an action on the walls of the blood vessels, which permits a free flow of blood to the gland, and thus renders secretion more active. The quantity of action in these two directions seems closely related to the vigor of food pressure, and all action ceases when the cavity is empty of food, so that this principle of action keeps an exact harmony between the needs and the supply of motive energy in digestion.

A similar result of contact influence has been traced more interiorly, as in the action of the kidney ducts. Here every drop of the secreted liquid which exudes from the kidney causes peristaltic motions in the walls of the duct, which act to produce a forward movement of the liquid.

From these considerations it becomes probable that another very important function is due to the same cause, although the idea of contact influence has not yet been applied to it. The pressure of the moving blood current upon the wall of the tubes through which it flows must act upon the nerves of those walls, so far as they are provided with sensory nerves. If so, the muscular motions of the heart and the arteries may arise from the irritation of nerve extremities by blood pressure. As the pressure of the current increases, the muscular contraction must grow more vigorous, so that a close harmony between cause and effect is established.

(To be continued.)